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Two Centuries of Rain

By J. GLASSPOOLE, M.Sc., Ph.D.

The occurrence of the wet year 1927 adds interest to an attempt to define the annual rainfall over England back to 1727. Homogeneous records at individual stations rarely cover more than 60 years, and it is only by using a number of overlapping records that it has been possible to compute the general rainfall for 200 years. These values are compared with that for 1927. The systematic collection of rainfall observations was first undertaken in this country about 1860, and at this time an endeavour was made to secure earlier records. These were summarised in the *Report of the British Association* for 1866, where general percentage values were given for each of the 140 years 1726 to 1865. The investigation was undertaken primarily to see if older records gave any indication of droughts comparable with those which had occurred during the dry years 1849 to 1858. The question had a practical bearing upon the proposed schemes for supplying large towns with water from considerable distances.

Attention has been directed from time to time to inaccuracies in the computations of these early general values, *e.g.*, the late Mr. G. J. Symons, F.R.S., pointed out the following errors in his own figures: the annual total for 1737 used for Lyndon (Rutland), of 29·94 inches should have been 20·94 inches (see *British Rainfall*, 1896, p. 10), and the record at Exeter was found to have become incorrect owing to the growth of a holly bush. Since the publica-

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tion* of general values for this country for the last sixty years, an attempt has been made to re-compute the values for earlier years, adopting the standard period, 1881 to 1915, and using all the available records.

No information is available for Wales, Scotland or Ireland in these years, so that any long series of annual general values must be confined to England. The computation of such a series was undertaken in three stages, viz., 1868 to 1926, 1820 to 1867 and 1727 to 1819, commencing with the period of most numerous data, and so working to the early years of few records.

Annual values for England and Wales, Scotland, Ireland and the British Isles from 1868 to date were first published in the *Meteorological Magazine* for June, 1923, p. 102, where the method employed is described. The values for England set out in Table I. were computed at the same time, but they have not been published hitherto. Maps were also prepared to show the mean fall of each successive decade from 1870 as a percentage of the standard 35 years' average. Similar maps for earlier decades were subsequently prepared to give a series of ten maps covering the 100 years 1820 to 1919, using all the complete records for any decade. The percentage values plotted on the maps were computed either by using the average for the station for the period 1881 to 1915, or, if the record covered two or more decades, by reading off the percentage from the latest map, which would have fullest data, to give values on the earlier maps. In the case of the decade 1820 to 1829 the map is drawn from the records from 14 fairly well distributed stations, and more recent decades from 35 or more stations. The general fall for each decade estimated from the maps is set out below, together with the two earlier estimates by Mr. Symons:—

	Decadal Maps, 1928, percentage of average, 1881-1915.	British Rainfall, 1881, percentage of average, 1830-1879.	British Association, 1866, percentage of average of long but indefinite period.
1820-9	103·5	—	103·2
1830-9	102·5	101·4	101·4
1840-9	102·9	100·1	102·6
1850-9	95·5	93·0	95·2
1860-9	101·4	100·4	101·5

The general values back to 1820 originally computed by Symons are therefore well supported by the present investigation, in which additional information has been used. The new series is 1·8 per cent. and 0·4 per cent. greater than those pre-

* See *Meteorological Magazine*, 58 (1923), p. 102.

viously obtained using different periods as the standard. The method adopted to obtain the annual percentages for the years 1820 to 1867 referred to the period 1881 to 1915, was to take the means of the annual values corresponding with the decadal values in the third and fourth column, and to increase them (generally by 1 per cent.) to give the decadal values set out in the second column. This extends the series of annual percentage values, using the average of the period 1881 to 1915 back to 1820, *i.e.*, to include the years of the cholera epidemics of 1831, 1853 and 1865, and the wet years between 1836 and 1850 "that rained away the corn laws."

For decades before 1820 there is not sufficient information on which to construct percentage maps, so that the critical examination which was rendered possible by such a procedure could not be carried out here. For this period about twice as many records as used by Symons were employed. The average for each station for the period 1881 to 1915 was determined, either from more recent records or from overlapping records, and the rainfall of each year expressed as a percentage of the average. For each year back to 1775 at least six records were available, back to 1757 at least three, and from 1756 to 1727 at least two. The individual values for each year are in reasonably close accord, and the mean was taken in each case to give the general value for England. It may be of some interest to recall that the series goes back practically to the commencement of the Chelsea Waterworks Company, when both the site and the Thames were considered suitable for the abstraction of water for drinking purposes.

A comparison has been made between the mean of the annual percentage values for two stations and the general mean given in Table I. for the 50 years, 1870 to 1919. The two stations were chosen as near as possible to those used to obtain the earliest 30 values of Table I. The series derived from two records gave generally larger departures than the general values (the mean deviation being 14·0 compared with 11·6). The individual values were generally in close agreement, differing by more than 10 per cent. in only 5 years, the largest departure being 17 per cent. This gives some indication of the probable error in the early years of the series. The correlation coefficient between the two series is +0·92.

The present series is in substantial agreement with the earlier values back to 1770 (except in 1774), about 10 per cent. greater from 1760 to 1740, and again in reasonably close agreement in the earliest years. In 1774 Mr. Symons's value of 129 per cent. is based only on the record at Lyndon (Rutland). This is confirmed by a record in the district, but elsewhere the rainfall was much more nearly normal, and the general value given in

Table I is 105 per cent. The main feature of the table is the frequency of dry years from 1730 to 1766. Many are confirmed by early weather diaries. According to Dr. T. Short, of Sheffield, 1731 to 1734, was "mostly droughty. Springs failed in most places," and "December to the first week in June (of 1741) was almost one continued drought." It is not possible to make a quantitative comparison from these historic records, but no drought during the last 200 years appears to have equalled that

TABLE I.

General Rainfall over England as per cent. of Average, 1881 to 1915.

Year	1720	1730	1740	1750	1760	1770	1780	1790	1800	1810
	%	%	%	%	%	%	%	%	%	%
0	—	85	77	75	100	107	78	91	95	98
1	—	66	67	116	96	79	86	104	99	97
2	—	94	80	95	89	111	121	123	89	102
3	—	84	69	100	123	112	99	87	85	91
4	—	116	100	85	107	105	95	101	94	99
5	—	101	103	97	88	111	82	90	86	97
6	—	109	92	106	87	98	96	88	103	106
7	103	96	104	98	99	96	102	111	90	102
8	112	77	87	100	136	102	69	89	91	104
9	102	103	90	91	91	94	118	107	99	104
Total	—	931	869	963	1016	1015	946	991	931	1000

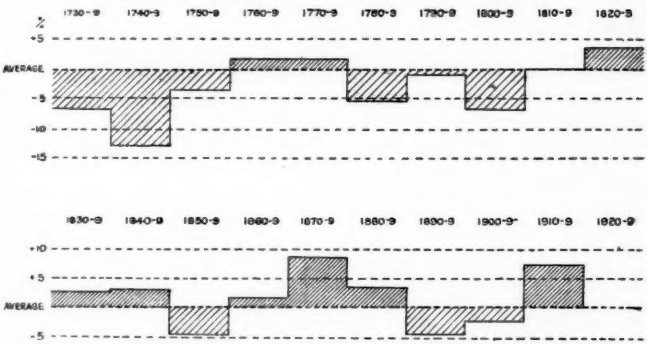
Year	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910	1920
	%	%	%	%	%	%	%	%	%	%	%
0	91	111	89	92	122	81	115	90	109	113	105
1	112	114	124	88	93	97	110	111	87	93	69
2	98	98	95	137	106	144	127	95	84	126	106
3	114	105	109	100	91	89	108	83	128	96	112
4	117	90	86	77	78	93	86	108	88	108	120
5	96	99	97	87	107	116	102	96	86	112	107
6	84	114	106	94	114	118	117	94	101	115	102
7	103	88	96	97	100	125	74	100	99	99	124
8	118	91	129	81	99	111	98	86	90	106	—
9	102	115	98	102	104	110	95	94	106	105	—
Total	1035	1025	1029	955	1014	1084	1032	957	978	1073	—

during 1252 to 1255, which included "the greatest drought in England," according to Dr. T. Short, or 1716, when "thousands of persons passed across on foot, under the arches of London Bridge." The latter case is perhaps more striking as presenting the antithesis of the recent disastrous floods in London. On September 14th, 1716, following the drought, a strong west-south-west wind not only prevented the tide from coming in for twenty-four hours, but drove forward the fresh water so that there was only a narrow channel in the middle, some 10 yards wide and very shallow.

The three wettest years in the series were 1768, 1852 and 1872,

with 136, 137 and 144 per cent. respectively. There was no year as dry as 1921, with 69 per cent., since 1788. The values for the years 1731, 1741 and 1743 are equally small, but as they are based on few records the departures from the normal are likely to be larger than the proper amount, and it is therefore reasonable to conclude that no year drier than 1921 occurred in the last two centuries. It would be expected that as the departures from the average are greater in the wettest years than in the driest years, years with a rainfall below the average would be more numerous. That is the case, for out of the 200 years, 87 were in excess of the average rainfall and 106 were deficient, the percentage being 100 in the remaining 7 years.

There were 9 consecutive wet years from 1875 to 1883, but the longest run of dry years was only 6, viz., from 1800 to 1805. The recent values are remarkable in that out of the last 14 years only two, 1921 and 1917, received less than the average. There



General Rainfall, England, Decadal means 1730 to 1919 as percentage departures from average 1881 to 1915

is no other run of wet years in the series comparable to this, but as many as 14 out of the 16 years 1800 to 1815 were dry. It is noteworthy that the deficiency of 1921 was more than made up in the following three years.

For the 100 years 1827 to 1926, the computed fall is rather more than that of the standard period 1881 to 1915, while that of the 100 years 1727 to 1826 is rather less than the average, the mean percentage values being 101·9 and 96·6 respectively. The diagram illustrates that there have been two runs of three consecutive dry decades, and one of two decades. Similarly, there were two runs of three consecutive wet decades and one of two decades. The decade 1810 to 1819 received the normal fall with 5 wet and 5 dry years.

Conclusion. A series of 200 annual values for the rainfall

of England is set out in Table I. The values back to 1820, *i.e.*, for over 100 years, are well supported, those for the preceding 50 years, although less reliable, are based on at least six records, and the earlier values, while necessarily even less reliable, are based on at least two records which support each other. The fall over England during 1927 of 124 per cent. has been exceeded in eight years out of the last 200. The three years 1768, 1852 and 1872 were markedly wetter than 1927.

Observations of Temperature and Humidity in certain Occluded Cyclones

In the February and March numbers of *Ciel et Terre* for 1927, Jaumotte discusses some observations of the temperature, pressure and humidity in the upper air made near Brussels with the aid of aeroplanes, in order to see whether these confirm the views advanced a few years ago by V. and J. Bjerknes, H. Solberg, and other Norwegian meteorologists, with regard to the structure and evolution of the cyclones of temperate latitudes.

By far the most interesting of these soundings was one made on July 2nd, 1924. At that time an area of rain, associated with a deep depression northwest of Ireland, was approaching Belgium. This depression was in the "occluded" stage: at 6 p.m. on June 30th, when centred north of the Azores, it had shown a warm sector on its southern side, characterised by damp warm southwest winds, obviously of equatorial origin, which soon disappeared from the level of the sea to be replaced by cool westerly winds of polar origin. In Fig. 1 a section through such an occluded cyclone is shown.

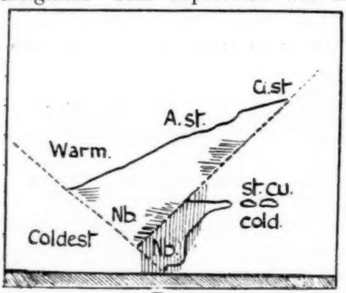


FIG. 1.

The general air movement is supposed to be from left to right, and the dotted lines showing the boundaries of the occluded warm air are shown some hundred-fold more steeply inclined to the horizontal than would normally be the case. The sounding under discussion was made in that part of the diagram where stratocumulus clouds are indicated, and should reveal at a certain height a surface of discontinuity where the occluded warm air is first encountered. Examination of Fig. 2, where temperature is plotted against pressure, and the relative humidity is written alongside, does in fact show such a transition at a height of about

12,000 feet, at the base of a thick sheet of alto-stratus or alto-cumulus cloud. There was in addition, at about 5,000 feet, a sheet of strato-cumulus and above it a slight inversion of temperature with very low humidity. A similar inversion to this last was found to be persistent in the southeast of England on the previous morning under anticyclonic conditions, and was not completely broken down by the rise of temperature in the

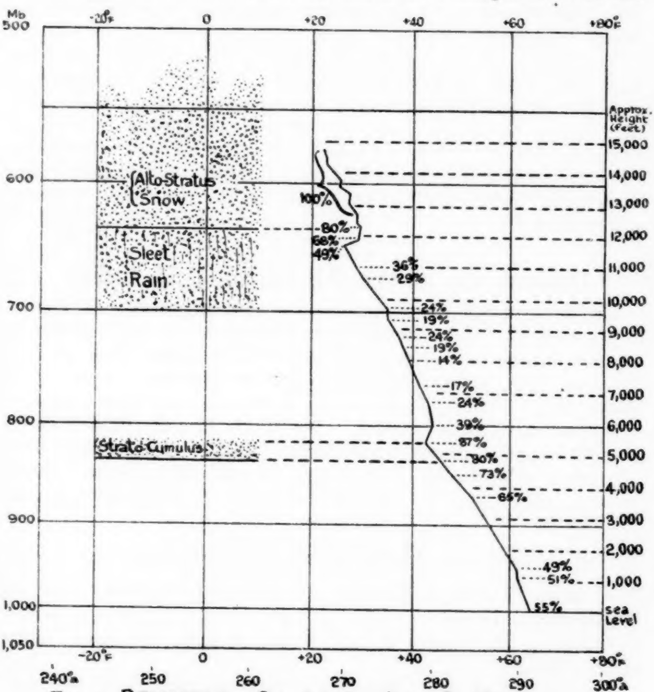


FIG. 2 BRUSSELS, 8h. G.M.T. JULY 2, 1924.

middle of the day. Its presence at the time of our ascent may be regarded as of little importance in regard to the evolution of the depression.

The most interesting point in connexion with this sounding is the strong evidence that the air above 12,000 feet had actually been resting upon the surface of the sea north of the Azores, about a day and a half earlier. An average speed northeastwards of 32 m.p.h. would have brought the air to Belgium at the correct time, a speed which is in good agreement with the average

upper winds deduced from the pressure gradient out on the Atlantic, and from such French pilot balloon ascents as were available at about the time when the air passed over northwest France. Moreover when the temperature was calculated, to which air on the sea in the warm sector should fall after reduction of its pressure to the value of 643 millibars found at the bottom surface of the warm damp air above 12,000 feet over Belgium, the result agreed to within about a degree with the temperature of 29° F. actually observed at that surface.

In another interesting ascent through an occlusion, made on July 10th, 1925, the base of the warm moist air was encountered at about 11,500 feet, and in a second ascent about five hours later, when the main mass of occluded air should have been nearly overhead, it was encountered at about 9,000 feet. In this case, and also in two further examples of occlusions, the Norwegian conception of occluded cyclones receives definite observational support.

E. V. NEWNHAM.

Discussions at the Meteorological Office

The subjects for discussion for the next meetings will be :—

February 27th. *Uber den Einfluss des Golfstromes auf die Winter temperatur in Europa.* By J. W. Sandström (Met. Zs. 43, 1926, pp. 401-11). *Opener*—Mr. A. Walters.

March 12th. *Ratio of heat losses by conduction and by evaporation from any water surface.* By I. S. Bowen (Physic Rev., Minneapolis, Minn., 27, 1926, pp. 779-87). *Evaporation from lakes.* By N. W. Cummings and B. Richardson (*idem.*, 30, 1927, pp. 527-34) and other papers. *Opener*—Mr. R. Corless, M.A.

Royal Meteorological Society

The Annual General Meeting of this Society was held on Wednesday, January 18th, at 49 Cromwell Road, South Kensington, Sir Gilbert Walker, C.S.I., F.R.S., President, being in the chair.

The Report of the Council for 1927 was read and adopted, and the Council for 1928 duly elected, the new President being Sir Richard Gregory, D.Sc., LL.D.

The Symons Gold Medal, which is awarded biennially for distinguished work done in connexion with meteorological science, was presented to Professor Dr. Hugo Hergesell, Hon. Mem., Director of the Aeronautical Observatory, Lindenberg. After receiving the medal, and thanking the Fellows of the Society for the award, Prof. Dr. Hergesell delivered a short address on "The Observation of Clouds with special reference to the safety of Aviation." The address described the methods in use at

Lindenberg Observatory, where soundings of the air up to 3,000 metres or more are made regularly twice a day, by means of kites, kite-balloons or captive balloons, according to the wind velocity. From the records of temperature and especially humidity obtained in this way, the heights and thicknesses of the different cloud layers can be deduced, and this information is then included in the reports broadcast from the Observatory. At Tempelhof, meteorological aeroplane flights are made whenever possible, the aeroplane being equipped with a horizontal gyroscope for flying through cloud. Other information about cloud heights and movements is obtained by the use of an inverting range finder.

Sir Gilbert Walker also delivered an address on " World Weather," of which the following is an abstract :—

Comparisons by graphical methods of variations of pressure, temperature and rainfall have during the past half century brought to light a number of relationships between conditions at places separated by considerable distances ; and then these have in recent years been studied systematically by taking 30 centres widely distributed over the earth and calculating by statistical methods the relationships between their seasonal values. It appears that there are three main oscillations or swayings :— (1) the North Atlantic, (2) the North Pacific, and (3) the Southern, affecting the Pacific and the Indian Oceans. These relationships have obvious applications for seasonal forecasting.

Correspondence

To the Editor, *The Meteorological Magazine*

Weather and Antiquaries

In your article on the above subject, you mention that a shingle bar grew across the mouth of the Little Hundred River in Suffolk in the thirteenth or fourteenth century.

In this connexion it is well to recall that " a great convulsion of the elements " is noticed by all the chroniclers in 1287. One effect of that storm was to submerge Winchelsea and Boomehill, to break up the sandbanks on which they stood, and to change the course of the River Rother from its former artificial channel to that which it now follows on its passage to the sea by Rye.* The choking up of the Priory Brook at Hastings and the successive loss of two harbours by that town may be difficult to date exactly. Corresponding changes at Seaford, Pevensey, Hythe, Folkestone and other places on the south-east coast have attracted much attention, and have invariably been attributed to the " Law of Eastward Drift," of which Prof. Burrows had

* Cinque Ports. By Montagu Burrows, ed. 1903, p. 16.

so much to say. The Royal Commission on coastal erosion generally accepted this explanation of the records.

Nevertheless, the accumulation of evidence pointing to substantial variations in rainfall seems to call for a reconsideration of this matter. Has this eastward drift of shingle been constant, and if not what are the causes of its variation ? Have fluctuations in the discharge of these streams affected the growth of shoals at their mouths ? If so, have such fluctuations been due to changes in rainfall or to more recondite alterations in underground drainage ? All these questions seem to demand fresh consideration, especially in view of the curious evidence of climatic changes from Greenland.

In the first instance, the solution of such problems must be dependent upon the adequate collection of facts by archæologists, geologists and meteorologists. At present data are lacking, and further search for records is of prime importance. As soon as the history of these changes can be written clearly and with certainty, there can be no doubt that it will deserve the most careful attention of those practical men in whose hands rests the future policy of the country in the matter of the choice of sites for new ports, and in the development of those which already exist.

Your reference to the drought in Sussex in the time of St. Wilfrid (A.D. 681), recalls a notable achievement by a Kentish saint which must have been nearly contemporaneous. Unfortunately I am unable to give the original reference to Capgrare's *Nova Legenda Angliae*, but this source is quoted in Lambarde's *Perambulation of Kent*, ed. 1826, p. 152, when we are told of St. Eanswide " that she haled and drewe water over the hils and rockes against nature from Swecton a mile off to her Oratorie at the sea-side." This seems to be an account of the first (post-Roman) artificial water-supply in the country. St. Eanswide was the daughter of Eadbald, King of Kent (616—640), and was the first Prioress of St. Peter's Priory near Folkestone. Her portrait is to be seen on the seal of the Mayor of that town reproduced on p. 812 of Boy's *Collections for a History of Sandwich.*

GEORGE M. MEYER.

1, *Victoria Terrace South, Low Fell, Gateshead. November 24th*, 1927.

The Cold Weather of December at Guernsey

The bitterly cold weather of the last half of December in England, extended its ramifications to Guernsey, where the month's mean temperature, 41·8° F., made it the coldest December at this station for at least 34 years. The previous coldest December was that of 1917, mean 41·9° F. The coldest day last month,

the 18th, gave a minimum temperature of 23·4° F., and a mean of 26·4° F. The lowest maximum, 29·1° F. occurred the next day. To find a colder day than December 18th, which was as much as 19·5° F. colder than the normal, we have to go back to the still memorable February of 1895.

Last month's intense cold was of short duration (5 days), and the snap that followed in the ending week of the year was much less severe as regards cold, but the strength of the easterly gale isolated the island from the mainland for the 3 days, 26th to 28th—an unprecedented occurrence.

One remarkable feature of both cold snaps was that not a flake of snow fell—a fortunate immunity in which I believe all the islands of this favoured group participated.

BASIL T. ROWSWELL.

Les Blanches, St. Martin's, Guernsey. January 23rd, 1928.

Cloud at Leysin

I read in the Press that half Europe is under fog, and it occurred to me, you may be interested to learn how it appears from my mountain perch (4,500 ft.). For about ten days, perhaps less, we have not seen the Rhone basin (the 20 miles of its length previous to its entering Lake Geneva) at all, on account of a dense layer of cloud lying below us. This layer has remained nearly stationary night and day throughout that time. Its upper face is as clean cut as it could be, like the most perfectly defined cumulus you ever saw. This face has varied from perfectly even, through small billowy tufts, to sometimes long undulating waves of the ocean roller type. With the sun glinting their tops they are a magnificent picture. The top of this layer has been for the most part at about 2,500 ft. (the Rhone at this point is 1,500 ft.), but the layer seems to be suspended in very critical equilibrium, because it slowly rises and falls. It will rise perhaps 500 ft. in an hour and as slowly recede. Yesterday and to-day it has been gradually rising, and has attained about 4,000 ft. to-day.

Local disturbances are quite common—a small area will appear to boil slowly, so that a hemisphere will rise above the mean level, like a man's bald head; sometimes these disturbances take the form of a small local horizontal whirl. I ought perhaps to explain this sea of cloud in our view is 7 miles wide and upwards of 25 miles long. The sky above varies from fully overcast (only rarely), half overcast with cirrus to pure blue sky. These higher clouds have not descended lower than 8,000 ft. and have been generally over 15,000. I quote these figures fairly confidently, because I know the heights of the various peaks around, and it is remarkable that if the clouds are

at 8,000 on one side of the plain they will be the same height almost invariably on the other side 7 miles away.

I was noticing a peculiar thing to-day. The upper clouds were at perhaps 12,000 ft., the fog layer top-face about 4,000 ft. Both appeared to be perfectly motionless and yet a good breeze was blowing at my level, 4,500 ft., showing that a strata of air can move swiftly along without, by friction, disturbing the upper and lower faces. Another pretty sight is to see waves of this layer roll along to the mountain side and swish up it like a wave upon a beach. The only difference is that the wave rises up the mountain concave upwards, *i.e.*, they do not roll in as billows do on a sea-shore but as a wave strikes the face of a cliff and curls upwards. It takes a quarter of an hour to complete the phenomena and often much longer instead of the usual few seconds.

The photograph in the frontispiece shows the view of Les Dents du Midi from Leysin in December, 1927. The distance across the clouds is 7 miles and to Les Dents du Midi in the centre of the view is 13 miles. The top of the clouds is about 4,000 feet and the valley is 2,500 feet below the cloud surface. It appears that the cloud sometimes reaches the ground below, but not always.

J. J. SHAW.

Mon Repos, Leysin, Switzerland, December 1st, 1927.

The Significance of Correlation Coefficients

In 1921 there was published in the *Meteorological Magazine* a note in which the following rule, due to Mr. W. H. Dines, was stated.*

"If there is a cause X and a result Y with a correlation r between them, then in the long run X is responsible for r^2 of the variation of Y."

Mr. Dines did not give a general demonstration, and my proof, which was printed in the note, was not quite satisfactory. Consideration of the criticisms which have been made has convinced me that the difficulty lies in the wording of the rule: there is no difficulty in demonstrating a certain mathematical equation. It is a matter of opinion whether the rule as enunciated by Mr. Dines is equivalent to this equation.

Let X and Y be corresponding values of two variables. No assumption need be made as to which is cause and which is effect. Let the means of n values of each of the variables be taken, and let x and y be the departures of X and Y from these means. Let σ_x and σ_y be the standard deviations. Further,

* Vol. 56 (1921) p. 20. The letters X and Y have been written for Mr. Dines's A and M.

let r be the correlation coefficient determined by the n values of x and y. By definition

$$n\sigma_x^2 = \Sigma x^2, \quad n\sigma_y^2 = \Sigma y^2$$

and

$$nr\sigma_x\sigma_y = \Sigma xy$$

Now consider the approximation to y, which can be obtained by the use of a relation such as

$$y^1 = \alpha x$$

in which α is a constant and y^1 is the required approximation.

We know that, if the approximation satisfies the condition that $\Sigma(y^1 - y)^2$ is as small as possible, then the coefficient α must be given by the equation

$$\alpha = r\frac{\sigma_y}{\sigma_x}$$

The equation for determining y^1 is therefore the "regression equation"

$$\frac{y^1}{\sigma_y} = r\frac{x}{\sigma_x}$$

On the other hand, x is related to y by the equation

$$\frac{x}{\sigma_x} = r\frac{y}{\sigma_y} + \xi$$

in which ξ is written for a quantity not correlated with y, the sum $\Sigma y\xi$ being zero.

It follows that $\quad y^1 = r^2 y + r\sigma_y\xi$

This equation may be written

$$y^1 = r^2 y + \eta \qquad \ldots\ldots\ldots\ldots(A)$$

Here η, being identical with $r\sigma_y\xi$, is not correlated with y.

With the equation (A) we may associate the relation

$$\sigma_{y^1} = r\sigma_y \qquad \ldots\ldots\ldots\ldots(B)$$

which is an immediate deduction from the regression equation.

The significance of (A) is that the computed variations of y^1 are equivalent to r^2 of the true variations of y, combined algebraically with random, irrelevant variations. This statement embodies my interpretation of Dines's rule.

The significance of (B) is that the variations of y^1 are on a scale smaller than those of y in the ratio r to 1. This equation of itself gives no information as to whether the variations of y^1 and y are in sympathy with each other.

The point which I want to emphasize is that the equation (A) justifies us in regarding r^2 as the figure of merit of a correlation coefficient r. It is r^2 which measures the advantage which will be derived from the use of a correlation coefficient in forecasting weather, or in any similar application of statistics.

Owing, I presume, to the reluctance of the Editor to inflict mathematics on the readers of the *Meteorological Magazine*, the foregoing note has been awaiting publication for some months. Meanwhile two notes on the subject by Sir Gilbert Walker and

Dr. Woolard have appeared in the *Monthly Weather Review.** Sir Gilbert is unable to find any use for Dines's rule. Dr. Woolard cuts down its utility by saying " if, as frequently happens," a certain term " is practically zero," then the rule holds.

Under these circumstances it seems best to admit that the original wording of the rule is so misleading that it must be discarded entirely. The new rule which I want to substitute is not a statement about cause and effect, but a statement about the application of regression equations. It runs as follows :

If the correlation coefficient for two variables X and Y is r, and if the appropriate regression equation is used for estimating X from known values of Y, then x^1, the estimated departure of X from the mean, is related to x, the true departure of X from the mean, by an equation of the type

$$x^1 = r^2 x + \xi$$

in which ξ is a variable quantity not correlated with x.

The rule involves no assumptions as to the distribution of the values of x and y and no assumption as to the existence of other correlated variables.†

As an example of the new rule, consider the following example. Suppose that the correlation coefficient for annual rainfall at two places is ½. The average rainfall at A is 20 inches. I know that the rainfall at A in a particular year is 28 inches ; you know the rainfall at B for that year, and estimate the rainfall at A by using the regression equation. " On the average " your estimate will be 22 inches. There is no reason to suppose you will estimate more than 22 inches rather than less. The helpfulness of the correlation in estimating the rainfall at A is evidently measured by the value of r^2, which is ¼.

F. J. W. WHIPPLE.

Remarkable Hailstorm

Mr. C. S. Durst has drawn my attention to an interesting paper by Becquerel communicated to the Académie des Sciences on November 13th, 1865, entitled " Mémoire sur les zones d'Orages à Grêle." In this paper is given a description of a remarkable hailstorm observed at Clermont-Ferrand on July 3rd, 1863. The day in question was exceedingly hot, and by 3 p.m. the sky was covered by an enormous nimbus cloud, with flashes of lightning in quick succession. About 6 p.m. there rapidly approached from west a cloud whose height was estimated to be

* *M.W.Rev.*, Washington, 55 (1927), pp. 459, 460.

† In the notation which I have introduced elsewhere

$$\xi = r\,(1 - r^2)^{\frac{1}{2}}\,\sigma_x\,\mathrm{Ca}$$

Ca being written for a casual number which has the standard deviation unity and is not correlated with x.

about 1,500 metres, whose form resembled a huge net. The portions of the network showed violent agitation, and soon after the arrival of the cloud there was a violent hailstorm lasting for about five minutes, the hailstones having the size of nuts. During the fall of the hail there was no wind. The most remarkable feature of this particular storm was the distribution of hail over the ground. The fall of hail was so violent that it caused considerable damage wherever it fell. M. Lecoq, who observed the storm, and described it in the *Comptes Rendus*, Vol. XXXVII, p. 75, stated that the damage produced by the hail was limited to small patches, which were surrounded by undamaged zones, forming a network whose meshes were irregular, but roughly 60 to 100 metres apart.

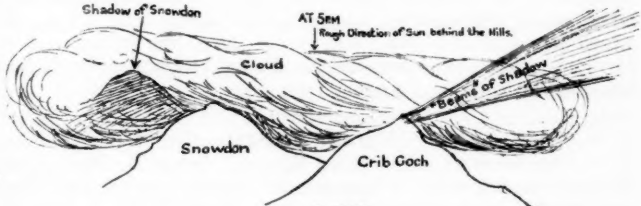
The distribution of hail corresponds to the form of the lower cloud which form recalls Bénard's cellular divisions in unstable liquids, a note on which appeared in the *Meteorological Magazine* for February 1925, p. 1. I should be very much interested to know whether any further observations of similar distribution of hail or rain have ever been noted, since they have a very definite bearing on the physics and dynamics of the atmosphere.

D. BRUNT.

[A brief scrutiny of the literature failed to show any similar case.—Ed. *M.M.*]

A Sideways Mirage

Perhaps the following phenomena of the sky which I observed during a walk from Capel Curig to Pen-y-Gwryd may be of interest to you, while if you can suggest an explanation it will satisfy a natural academic curiosity of the writer.



Oct. 11, 1927

At 17h. 5m. G.M.T. on October 11th, the sun had fallen behind the Snowdon range, and the range was backed by a large golden, fleecy cloud, on which was outlined a dark, well-defined shadow of Snowdon, persisting for some five or ten minutes. I find it difficult to understand how the shadow was cast in the direction of the sun, as the cloud was manifestly on the far side of the hills, the atmosphere was clear, and the eastern sky was almost cloudless.

At 17h. 20m. the cloud had disappeared, and the western horizon was clear except for some distant striations, when suddenly there appeared over Crib Goch a streaky golden outline of its summit, which faded out after perhaps 15 seconds or half a minute.

W. G. EMMETT.

Elm Avenue, Beeston, Nottingham. October 12th, 1927.

[Cases are on record in which sideways mirages have been observed. A mirage is the appearance assumed by a single object which can be seen in two different directions simultaneously: in one direction the rays of light may proceed in straight lines from the object to the eye; in the other they may be bent slightly, owing to the refraction effects in air of varying density. The second image of Snowdon would in that case be reversed (*i.e.*, right to left and left to right).

Sideways mirages are much rarer than vertically displaced mirages, and the appearance of Crib Goch seen later might perhaps be explained as an ordinary mirage as often seen in air arranged in layers of varying density.

It would be difficult to say how the varying densities were produced, but it may perhaps be tentatively suggested that as the air was apparently clear, the temperature of the air in the shadow of the mountains might fall rapidly as the shadow increased in extent, so that appreciable temperature differences would form near the boundary of the shadow.—R. CORLESS.]

Road Mirages

In connexion with the letter on the above subject by Mr. T. W. Vernon Jones in the December number of the *Meteorological Magazine*, Mr. H. E. Wimperis, M.A., calls our attention to a letter which appeared in *Nature* dated August 20th, 1903, and which was quoted in the *Daily Telegraph* of the following day. In this letter Mr. Wimperis described a road mirage which he had observed in Putney on August 17th, 1903.

Mirage at Sea

In an interesting note on "Road Mirages," in the December issue of the *Meteorological Magazine*, the writer points out that one would expect the temperature distribution of the air, which is supposed to be responsible for the phenomenon, would be disturbed by the constant passing of vehicles.

Although not dealing with land surface, it may be interesting to hear of the formation of mirages of ships as seen from the Meteorological Office, Holyhead. From Salt Island the only unrestricted view of the sea is towards north-northeast, and the ships passing Carmel Head are some ten miles away. The shapes of these ships are distorted when the temperature of the

sea is higher than the temperature of the air, and the visibility is such that the ships can be seen clearly, but it would seem that wind force makes no difference to their formation.

It is suggested that in this case the mirage is not formed by the temperature distribution of the air near the sea, but by the differences of temperature of the sea itself and the temperature of the air above it.

It would be interesting to compare the reflecting powers of the two surfaces (road and sea). H. L. PACE.

Salt Island, Holyhead. December 23rd, 1927.

NOTES AND QUERIES

The Thames Floods of January 7th

Shortly after midnight on January 7th, an abnormal rise of the Thames occurred, the tidal reaches of the river attaining their highest level for at least fifty years. Serious flooding resulted in the City, Southwark, Westminster and as far west as Putney and Hammersmith. In the low-lying areas fourteen people lost their lives, through being trapped in basements, and a very large amount of material damage was done by the water.

After the Christmas snowstorm, a thaw set in gradually on December 31st and January 1st, and was general by January 2nd. Flooding became widespread in the Thames valley above London, but the areas affected were chiefly those in which floods occur almost every year. During the first week of 1928, the rainfall in London and Surrey generally averaged about one inch, which is nearly twice the normal for the week. The river continued to rise, the flow at Teddington weir, as reported in *The Times*, increasing from 5,200 million gallons on January 1st to 9,500 million gallons on January 7th, by which date, however, a gradual fall had set in along the upper reaches of the river. The river was thus already in a swollen condition, but the severity of the flood in London appears to have been due more to the circumstance that a spring tide coincided with high winds from the north-west in the North Sea than to the water of the river itself.

On January 6th, at 1 a.m. a depression was approaching the Hebrides and the centre of this depression moved east-south-east at a rate of about 60 m.p.h. towards Denmark. In its rear there was a steep pressure gradient, and the winds rose rapidly, probably reaching gale force during the evening over most of the North Sea between the English coast and Holland. Over east and south-east England and the eastern Channel, the winds blew strongly from between south-west and west during the morning, and veered towards north-west in the afternoon. Winds up to gale force prevailed until 6 p.m., but later in the

evening there was a general decrease of wind force, and by 1 a.m. on the 7th, the winds over south-east England had fallen light, but it seems that by that time they had sufficed to drive large quantities of sea water into the estuary, to be carried towards London by the tide.

The predicted height of the tide in the early morning of January 7th was approximately 21 feet at London Bridge. On two occasions in recent years, September 26th, 1926, and November 1st, 1921, tides have occurred in the Thames sufficiently high to arouse Press comment. On each of these occasions the predicted height was approximately 23 feet ; it may be remarked that an even higher figure, 25 feet, was predicted for September 24th, 1926, associated with a combination of full moon and moon's perigee on September 21st. On this occasion, however (September, 1926), the winds were mainly light, and only minor flooding occurred, while in November, 1921, although the predicted height was about the same, the tram-lines on the Embankment were under water, and wharves in the City were flooded*; on this occasion, the weather conditions resembled those of January, 1928. On October 31st and November 1st, 1921, a depression moved rapidly east-north-east from between Iceland and the Faroes to central Norway. By 7 a.m. on November 1st, north to north-west gales were blowing over most of the North Sea, and these continued in the eastern part of the region for 24 hours, but by 1 p.m. the winds over east and south-east England had become mainly moderate. The flood occurred in the afternoon.

Some reference may be made to earlier floods in the Thames. In 1894, the flow at Teddington was recorded as 20,000 million gallons on November 18th, and enormous areas of country were under water.† *The Times* mentions that in 1882 occurred a high tide which swept away Charing Cross pier. In *Symons's Meteorological Magazine* for February 1869, p. 11, appears the statement under the heading " High Tides and Heavy Gales " : " Last year, the Thames rose to an unusual height, flooding the densely inhabited district of Westminster, which lies near the river, and overflowing the lowlands of Battersea and Chelsea, as far as Kew." On January 11th, 1877 ‡ "a high flood which had been accumulating from about Christmas, reached its maximum on this day . . . . as it synchronised with a very high tide, there was great destruction in Southwark and all the low-lying places along the river." In 479, the Thames was much flooded, both above and below London, and great damage was caused, but the earliest recorded

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* *Meteorological Magazine*, 56 (1921), p. 295.

† *Symons's Meteorological Magazine*, 30 (1895), p. 71.

‡ The November floods of 1894 in the Thames Valley. By G. J. Symons and G. Chatterton. *London, Q.J.R. Meteor. Soc.*, 21 (1895), p. 189.

Thames flood was in A.D. 9, when many inhabitants are said to have been destroyed.

The two following references of high tides in the Thames, contributed by Mr. Richard Cooke, of Detling, Maidstone, Kent, may also be mentioned.

From the *Journal of the British Archæological Association.* Vol. XXXII., Pt. II., Dec., 1926.

Page 171. "The Monastery of Bermondsey."

Bermondsey suffered severely from floods. In 1294 on October 18 there was a tremendous inundation when the Thames waters rushed through a great breach in the embankment at Rotherhithe and much damage was done. *Flores Historiarum,* Vol. III., page 93 Rolls Series.

Page 179.

In 1338 another inundation of the Thames did great damage and a respite of payment was granted. *Cal. of Close Rolls* 1333-7, p. 182.

S. T. A. Mirrlees.

Memoirs of the Royal Meteorological Society

In the *Meteorological Magazine* for July 1926, there appeared a description of the circumstances which led to the initiation of the series of *Memoirs,* with brief summaries of the first three of the series. The completion of the first volume of ten numbers affords us an opportunity of congratulating the Society on the success of this valuable new departure.

The titles and authors of the later numbers of the first volume are as follows :—

No. 4. "The variance of upper wind and the accumulation of mass," by L. F. Richardson, D. Proctor, and R. C. Smith.

No. 5. "The Nile flood and world weather," by E. W. Bliss.

No. 6. "British winters and world weather," by E. W. Bliss.

No. 7. "On the relation between temperature changes and wind structure in the upper atmosphere," by C. K. M. Douglas.

No. 8. "Geopotential and height in a sounding with a registering balloon," by Sir Napier Shaw.

No. 9. "On periodicity and its existence in European weather," by Sir Gilbert T. Walker.

No. 10. "The mean cloudiness over the earth," by C. E. P. Brooks.

The first volume of the *Memoirs* has thus already ranged over a large part of the field of meteorology, though as would be expected, the theoretical aspect predominates. The grant of £150 from the Government Publication Grant has again been renewed, and the Society has already made a start with volume 2 of the *Memoirs.*

Approximate Equations for the Determination at Cranwell of Screen Minimum Temperatures during Radiation Nights in Winter from Data of the preceding 15h.

Defining " winter " as the months October to March (inclusive) and a " radiation night " as one in which the mean cloud amount at 18h., 1h., and 7h. was four-tenths or less, this note embodies an attempt to determine for such radiation nights during winter the relation between the dew point at 15h. and the succeeding night screen minimum temperature measured at 7h. the following morning. The period brought under review stretched from October 1st, 1920, to March 31st, 1927. The thermometers employed have standard and very good exposures, on flat and open ground approximately 240 feet above sea level.

In determining the equations representing the relationships by the usual graphical method, a three-fold differentiation with regard to wind force during the night as measured by a Dines anemometer whose head is 43 feet above ground was made, taking the average of the readings at 18h., 1h. and 7h. as the deciding factor. The three wind groups were (A) a mean of 8 miles an hour or less, (B) a mean of between 8 and 15 miles an hour, and (C) a mean greater than 15 miles an hour. Each of these three groups was further sub-divided according as to whether the relative humidity at 15h. was greater or less than 85.

The equations obtained were as follows, where T = expected night screen minimum ; D = dew point at 15h. ; H = relative humidity at 15h :—

Mean Wind Speed	Value of H	Equation	No. of Cases available
8 m.p.h. or less	$H =$ or > 85 $H < 85$	$T = D-6$ $T = D-8$	32 33
8 m.p.h. to 15 m p.h.	$H =$ or > 85 $H < 85$	$T = D-1$ $T = D-4$	31 49
15 m.p.h. or more	$H =$ or > 85 $H < 85$	$T = D$ $T = D-2$	25 23

D and H being observed at 15h. and a mean value of the wind speed for the night forecasted, T may be obtained using the appropriate equation. The results so gained approximate with great fidelity to the readings actually registered. As would be expected, low relative humidity and a stagnant atmosphere both lead to low night minimum temperatures. It is possible that though the equations were derived from a consideration of

Cranwell data they may have an application considerably beyond Cranwell confines.

In all the cases heretofore treated D was greater than 32° F. There were, however, a few cases available in which D was less than 32° F., and although the number of these cases was insufficient to justify sound generalization, it was clearly to be noted that the values of T actually registered were considerably lower than those that would have been computed from the equations. It therefore needs to be emphasised that the equations only hold for values of D greater than 32° F.

W. H. PICK.
J. PATON.

Radiation from the Sky

RADIATION MEASURED AT BENSON, OXON, 1927.

Unit: one gramme calorie per square centimetre per day.

ATMOSPHERIC RADIATION only (dark heat rays)

Averages for Readings

		Oct.	Nov.	Dec.
Cloudless days :—				
Number of readings	n	4	3	0
Radiation from sky in zenith ...	π I	473	409	..
Total radiation from sky ...	J	501	435	..
Total radiation from horizontal black surface on earth ...	X	706	670	..
Net radiation from earth ...	X—J	205	235	..

DIFFUSE SOLAR RADIATION (luminous rays).

Averages for Readings between 9 h. and 15 h. G.M.T.

		Oct.	Nov.	Dec.
Cloudless days :—				
Number of readings	n_0	3	2	0
Radiation from sky in zenith ...	πI_0	40	11	..
Total radiation from sky ...	J_0	55	16	..
Cloudy days :—				
Number of readings	n_1	3	3	1
Radiation from sky in zenith ...	πI_1	78	43	15
Total radiation from sky ...	J_1	74	39	14

Unit for I = gramme calorie per day per steradian per square centimetre.
Unit for J and X = gramme calorie per day per square centimetre.
For description of instrument and methods of observation, see *The Meteorological Magazine*, October, 1920, and May, 1921.

Meteorological Observations at St. Kilda

During the months of May to August, 1927, meteorological observations were made at St. Kilda by Mr. J. Mathieson, F.R.S.E., who was at that time engaged on a survey of the island. The period is short, but as regular observations have not previously been available it seems desirable to put on record the results for the four months, together with a comparative statement indicating the nature and extent of the differences between the St. Kilda figures and the corresponding ones for Stornoway and Tiree.

Comparison of St. Kilda with Tiree and Stornoway

1927	Temperature					Rainfall			Sunshine	Mean Cloud
	Mean			Absolute						
	7h.	Max.	Min.	Max.	Min.	Total	Most in day	Date	Mean	7h.
	° F.	° F.	° F.	° F.	° F.	in.	in.		h.	0—10
May.										
St. Kilda ...	46·5	50·6	44·1	60	39	2·58	0·89	13	5·31 (27 days)	8·3 (30 days)
Tiree ...	48·2	53·7	44·1	72	32	2·11	0·63	13	8·69	6·2
Stornoway ...	45·4	51·5	40·0	63	28	1·81	0·35	13	5·54	7·8
June.										
St. Kilda ...	48·5	53·4	46·2	61	42	3·55	0·69	15	6·64	7·4
Tiree ...	50·2	55·1	46·3	64	40	3·33	0·71	15	7·78	6·9
Stornoway ...	49·5	54·6	43·2	63	35	3·76	0·43	27	6·47	7·7
July.										
St. Kilda ...	55·1	59·9 (30 days)	53·1 (30 days)	67	49	1·87	0·48	3	5·01	7·6
Tiree ...	56·2	61·5	52·7	68	45	3·28	0·79	29	6·40	7·2
Stornoway ...	56·1	62·3	50·7	67	43	3·92	0·71	29	5·63	7·7
August.										
St. Kilda ...	55·5	59·9	53·6	65	49	3·58	0·62	18	4·16	7·2
Tiree ...	56·1	62·3	52·2	67	44	2·35	0·39	7	5·04	6·9
Stornoway ...	54·6	62·5	49·6	71	37	2·72	0·47	25	5·44	7·7
4 months May-August.										
St. Kilda......	—	55·9	49·3	67	39	11·58	0·89	May 13	5·28	7·6
Tiree ...	—	58·3	48·8	72	32	11·07	0·79	July 29	6·98	6·8
Stornoway ...	—	57·7	45·9	71	28	12·21	0·71	July 29	5·77	7·7

It will be noted from the table above that the St. Kilda climate is slightly more "maritime," *i.e.*, the mean and the extreme maximum temperatures are a little lower and the mean and extreme minimum temperatures a little higher than at the two

other stations. In the matter of rainfall St. Kilda has a little more than Tiree and a little less than Stornoway, but the differences are small and the length of the period of observation is also rather too small to justify any generalization on this point. In the matter of sunshine St. Kilda is very decidedly less favoured than Tiree, the difference being supported by the relative cloud amounts at 7h., and it is rather less favoured than Stornoway, though the cloud amounts at 7h. come out in this case approximately equal.

A closer resemblance might exist possibly between St. Kilda and Barra Island, but it happens that only three of the months under discussion (May to July) are covered by simultaneous observations. Over that period mean maximum and mean minimum temperatures were each approximately a degree lower at St. Kilda. The total falls of rain are 8·00 and 8·23 inches respectively, and the mean daily amounts of sunshine are 5·65 and 6·89 hours, so that St. Kilda again comes out rather unfavourably in the matter of sunshine. The smaller amount of sunshine recorded arises, in Mr. Mathieson's opinion, from the number of occasions on which there was sufficient mist or haze around St. Kilda to prevent the sun marking the card in the recorder. This is borne out by the visibility observations, there having been at St. Kilda 36 cases, at Tiree only 6 and at Stornoway only 15 cases, where the most distant of the fixed "visibility objects" was the $1\frac{1}{4}$-mile or some nearer object.

The highest point on St. Kilda, Conochair, according to the recent survey, is nearly 1,400 ft. above mean sea level.

News in Brief

The Seventh Annual Dinner of the Staff of the Meteorological Office, Shoeburyness, was held at the Queen's Hotel, Westcliff, on Saturday, February 4th. Mr. D. Brunt, Superintendent for Army Services, was the guest, and Mr. C. Britton was in the chair. After the dinner an excellent entertainment was provided by members of the staff, consisting chiefly, in accordance with custom, of original items specially prepared for the occasion.

The Weather of January, 1928

In striking contrast to the cold, exceptionally snowy weather experienced at the end of December, 1927, January was almost throughout mild and unsettled. The winds were mainly southwesterly, strong on most days and frequently of gale force, while rainfall was much above the average, though sunshine was often abundant for the time of year. Some sharp frost occurred in the early morning of the 1st, Eskdalemuir registering a

minimum in the screen of 11° F., but the passage of a deep depression off Ireland caused a general rise in temperature with heavy rain in the southwest. In consequence the thick snow of the last weeks of December melted rapidly and floods occurred in many parts of the country. Further frost, though seldom severe, occurred sometimes at night in the fair periods between the depressions, but the latter passed in such rapid succession (generally to the northwestward of the British Isles) that there was no spell of quiet frosty weather. Day temperatures were generally high for the time of year, the highest maximum being 59° F. at Wisley on the 6th and 58° F. at Llandudno on the 21st. On the 6th a depression deepened near the Hebrides and moved southeastwards across the North Sea to Denmark, causing very high wind velocities, gusts of over 80 m.p.h. being recorded at Fleetwood, Southport and Spurn Head. The highest gust of the month, 87 m.p.h., however, occurred at Lerwick on the 24th, and gusts of about 75 m.p.h. occurred at one or more of the anemograph stations on the 8th, 10th and 23rd to 26th. Beaufort force 9 (49 m.p.h.) was reported at Edinburgh at 13h. on the 10th and at St. Ann's Head four times between 18h. on the 24th and 7h. on the 26th. On the 7th unusually high tides occurred on the Thames with flooding in London.* "Snow-lying" was reported frequently from Scotland and north England, and the rainfall showed a large excess in most parts of the country. At Stornoway (Hebrides) 10·5 in. constituted the largest January total there since records began in 1873, and at Bolton 11·33 in. was the largest January total for 97 years. Over 25 in. was recorded during the month in the English Lake District and in Snowdonia. At a few stations, *e.g.*, Keswick, Rhayader, Dean Park (Devon) and Mallarany, it rained every day of the month. Among the largest falls in 24 hours were 4·01 in. at Cwm Dyli (Snowdon) and 3·24 in. at Rosthwaite (Borrowdale) on the 12th, 3·14 in. at Didworthy (Devon) on the 1st and 2·73 in. at Treherbert (Glamorgan) on the 23rd. Thunderstorms occurred locally in Scotland and Ireland. The total sunshine for the month was above the average in many parts. At Dublin the sun shone for 86 hrs., which is 29 hrs. above the average, and at London for 58 hrs., which is 15 hrs. above the average. At Ross-on-Wye it was the sunniest January since records began 14 years ago. The greatest amount enjoyed on one day was 8·1 hrs. on the 27th at Torquay.

Pressure was below normal over northwest Europe, Spitsbergen and the northern part of the North Atlantic to Newfoundland, the greatest deficit being 14·8 mb. at Thorshavn, and above normal over southwest Europe, the Azores and Bermuda, the greatest excess being 8·4 mb. at Horta. South-

* See page 17.

westerly winds prevailed generally over northwest Europe. Temperature and rainfall were above normal in most parts, there being an excess of 45 per cent. in the rainfall of Svealand and southern Norrland in Sweden. At Zürich the temperature was 7° F. above normal and at Spitsbergen as much as 10° F.

After about 10 days' fine dry mild weather, sufficient snow fell in Switzerland on the 6th to make the ski-ing again good in most places above 3,500 ft. On the 9th, however, the weather became mild owing to the prevalence of the Föhn wind and continued so until the 17th when snow fell again and normal conditions were renewed until the end of the month. Owing to the high winds and alternate freezing and thawing many avalanches fell, land-slips were reported near Geneva, and accidents were numerous. Severe gales occurred in various parts of Germany on the 8th, and telegraphic communications were disturbed in Silesia owing to the heavy snowfalls. The floods in western Flanders extended considerably about the 10th with the heavy rain and thawing of the snow. The ice on the lower Danube was melting on the 25th, causing slight local floods. Many storms occurred over the North Sea.

Renewed floods in Algeria on the 3rd caused the roads in the Perregaux regions to become impassable again and several bridges collapsed. Heavy rain again fell on the 12th, and at the end of the month a heavy fall of snow destroyed most of the repairs done during the month.

Very cold weather with gales was reported from New York early in the year and severe gales were experienced along the Atlantic seaboard from eastern Canada to Florida on the 25th. On the 29th a heavy snowstorm occurred in the Eastern States, a fall of 10½ in. being reported from Washington.

Many severe gales occurred on the North Atlantic between the 16th and 31st.

The special message from Brazil states that the rainfall in the northern and central districts was scarce, being 1·2 in. and 1·8 in. below normal respectively, while that in the southern districts was irregular in distribution with a total 1·0 in. above normal. Two anticyclones passed across the country and the unusual occurrence of depressions in the high latitudes caused several storms. Temperature was high. The crops (except the sugar cane) were generally in good condition. At Rio de Janeiro pressure was 0·1 mb. below normal and temperature 1·1° F. below normal.

Rainfall, January, 1928—General Distribution

England and Wales ..	210	per cent. of the average 1881-1915.
Scotland	214	
Ireland	166	
British Isles	202	

202 is the largest January percentage since 1870.

Rainfall: January, 1928: England and Wales

CO.	STATION.	In.	Per-cent. of Av.	CO.	STATION.	In.	Per-cent of Av.
Lond.	Camden Square	3·60	194	*Leics*	Thornton Reservoir	4·44	224
Sur.	Reigate, The Knowle	4·42	197	,,	Belvoir Castle	3·77	213
Kent.	Tenterden, Ashenden	3·50	163	*Rut.*	Ridlington	4·70	...
,,	Folkestone, Boro. San.	3·80	...	*Linc.*	Boston, Skirbeck	3·48	215
,,	Margate, Cliftonville	2·58	161	,,	Lincoln, Sessions House	3·35	199
,,	Sevenoaks, Speldhurst.	4·22	...	,,	Skegness, Marine Gdns.	3 85	222
Sus.	Patching Farm	5·67	218	,,	Louth, Westgate	4·24	196
,,	Brighton, Old Steyne	5·10	211	,,	Brigg	...	...
,,	Tottingworth Park	6·87	254	*Notts.*	Worksop, Hodsock	3·42	193
Hants	Ventnor, Roy.Nat.Hos.	5·30	199	*Derby*	Derby	5·16	258
,,	Fordingbridge, Oaklnds	5·85	212	,,	Buxton, Devon. Hos.	10·76	241
,,	Ovington Rectory	6·88	255	*Ches.*	Runcorn, Weston Pt.	5·65	238
,,	Sherborne St. John	4·72	202	,,	Nantwich, Dorfold Hall	5·07	...
Berks	Wellington College	3·06	155	*Lancs*	Manchester, Whit. Pk.	7·68	306
,,	Newbury, Greenham	4·95	214	,,	Stonyhurst College	12·27	287
Herts.	Benington House	3·30	181	,,	Southport, Hesketh Pk	7·15	280
Bucks	High Wycombe	5·29	253	,,	Lancaster, Strathspey.	9·86	...
Oxf.	Oxford, Mag. College	3·46	201	*Yorks*	Wath-upon-Dearne	3·19	166
Nor.	Pitsford, Sedgebrook	3·79	204	,,	Bradford, Lister Pk.	8·12	282
,,	Oundle	2·72	...	,,	Oughtershaw Hall	17·84	...
Beds.	Woburn, Crawley Mill.	3·69	216	,,	Wetherby, Ribston H.	4 93	239
Cam.	Cambridge, Bot. Gdns.	2·97	198	,,	Hull, Pearson Park	4·26	236
Essex	Chelmsford, CountyLab	3·26	213	,,	Holme-on-Spalding	4·87	...
,,	Lexden, Hill House	3·06	...	,,	West Witton, Ivy Ho.	6·55	...
Suff.	Hawkedon Rectory	3·52	202	,,	Felixkirk, Mt. St. John	4·04	202
,,	Haughley House	2·60	...	,,	Pickering, Hungate	4·23	...
Norf.	Beccles, Geldeston	2·83	170	,,	Scarborough	3·90	195
,,	Norwich, Eaton	3·77	192	,,	Middlesbrough	2·73	171
,,	Blakeney	2·73	159	,,	Baldersdale, Hury Res.	6·65	...
,,	Little Dunham	4·71	242	*Durh.*	Ushaw College	3·28	160
Wilts.	Devizes, Highclere	4·42	203	*Nor.*	Newcastle, Town Moor.	2·25	110
,,	Bishops Cannings	4·00	172	,,	Bellingham, Highgreen	5·92	...
Dor.	Evershot, Melbury Ho.	7·09	204	,,	Lilburn Tower Gdns.	4·51	...
,,	Creech Grange	7·06	...	*Cumb*	Geltsdale	6·18	...
,,	Shaftesbury, Abbey Ho.	3·67	141	,,	Carlisle, Scaleby Hall	6·90	278
Devon	Plymouth, The Hoe	7·27	218	,,	Borrowdale, Rosthwaite	24·83	...
,,	Polapit Tamar	7·29	196	,,	Keswick, High Hill	12·16	...
,,	Ashburton, Druid Ho.	10·13	199	*Glam.*	Cardiff, Ely P. Stn.	9·51	252
,,	Cullompton	6·38	197	,,	Treherbert, Tynywaun	22·16	...
,,	Sidmouth, Sidmount	4·67	163	*Carm*	Carmarthen Friary	10·77	246
,,	Filleigh, Castle Hill	7·30	...	,,	Llanwrda, Dolaucothy.	12·63	238
,,	Barnstaple, N.Dev.Ath.	6·46	197	*Pemb*	Haverfordwest, School	7·89	171
Corn.	Redruth, Trewirgie	8·88	210	*Card.*	Gogerddan	9·17	224
,,	Penzance, Morrab Gdn.	8·25	218	,,	Cardigan, County Sch.	7·31	...
,,	St. Austell, Trevarna	8·14	190	*Brec.*	Crickhowell, Talymaes	6·60	...
Soms	Chewton Mendip	9·91	258	*Rad.*	Birm. W.W. Tyrmynydd	12·26	195
,,	Street, Hind Hayes	4·07	...	*Mont.*	Lake Vyrnwy	16·24	288
Glos.	Clifton College	...	...	*Denb.*	Llangynhafal	4·45	...
,,	Cirencester, Gwynfa	5·21	208	*Mer.*	Dolgelly, Bryntirion	10·80	190
Here.	Ross, Birchlea	4·63	191	*Carn.*	Llandudno	4·25	159
,,	Ledbury, Underdown.	4·21	191	,,	Snowdon, L. Llydaw 9	29·43	...
Salop	Church Stretton	6·04	239	*Ang.*	Holyhead, Salt Island.	6·03	207
,,	Shifnal, Hatton Grange	3·92	202	,,	Lligwy	7·59	...
Worc.	Ombersley, Holt Lock.	3·91	204	*Isle of Man*			
,,	Blockley, Upton Wold.	4·76	202		Douglas, Boro' Cem.	7·81	233
War.	Farnborough	4·58	213	*Guernsey*			
,,	Birminghm, Edgbaston	4·81	238		St. Peter P't. Grange Rd	6·48	221

Rainfall: January, 1928: Scotland and Ireland

CO	STATION.	In.	Per-cent. of Av.	CO.	STATION.	In.	Per-cent of Av.
Wigt.	Stoneykirk, Ardwell Ho	7·05	239	*Suth.*	Loch More, Achfary	13·77	189
,,	Pt. William, Monreith	7·75	...	*Caith*	Wick	4·70	191
Kirk.	Carsphairn, Shiel	18·14	...	*Ork*	Pomona, Deerness	5·18	150
,,	Dumfries, Cargen	11·83	296	*Shet.*	Lerwick	7·65	180
Dumf	Eskdalemuir Obs.	15·37	285	*Cork.*	Caheragh Rectory	9·78	...
Roxb	Branxholm	7·52	274	,,	Dunmanway Rectory	10·21	163
Selk.	Ettrick Manse	14·96	...	,,	Ballinacurra	4·14	104
Peeb.	Castlecraig	...	...	,,	Glanmire, Lota Lo.	5·80	135
Berk.	Marchmont House	4·64	206	*Kerry*	Valentia Obsy.	8·14	148
Hadd	North Berwick Res.	2·78	162	,,	Gearahameen	18·50	...
Midl	Edinburgh, Roy. Obs.	4·91	282	,,	Killarney Asylum	...	...
Ayr.	Kilmarnock, Agric. C.	9·67	283	,,	Darrynane Abbey	7·82	156
,,	Girvan, Pinmore	9·15	194	*Wat.*	Waterford, Brook Lo.	4·08	111
Renf.	Glasgow, Queen's Pk.	8·68	260	*Tip.*	Nenagh, Cas. Lough	6·38	161
,,	Greenock, Prospect H.	15·52	227	,,	Roscrea, Timoney Park	4·71	...
Bute.	Rothesay, Ardencraig	10·44	232	,,	Cashel, Ballinamona	4·52	119
,,	Dougarie Lodge	10·56	...	*Lim.*	Foynes, Coolnanes	5·98	158
Arg.	Ardgour House	20·10	...	,,	Castleconnell Rec.	6·55	...
,,	Manse of Glenorchy	18·88	...	*Clare*	Inagh, Mount Callan	9·46	...
,,	Oban	10·78	...	,,	Broadford, Hurdlest'n.	6·22	...
,,	Poltalloch	11·33	224	*Wexf*	Newtownbarry	6·86	...
,,	Inveraray Castle	21·28	259	,,	Gorey, Courtown Ho.	5·02	161
,,	Islay, Eallabus	10·42	223	*Kilk.*	Kilkenny Castle	4·19	131
,,	Mull, Benmore	15·20	...	*Wic.*	Rathnew, Clonmannon	4·25	...
,,	Tiree	...	...	*Carl.*	Hacketstown Rectory	4·22	119
Kinr.	Loch Leven Sluice	7·15	227	*QCo.*	Blandsfort House	4·32	132
Perth	Loch Dhu	22·35	246	,,	Mountmellick	6·56	...
,,	Balquhidder, Stronvar.	17·07	...	*KCo.*	Birr Castle	3·89	138
,,	Crieff, Strathearn Hyd.	10·16	252	*Dubl.*	Dublin, FitzWm. Sq.	2·23	97
,,	Blair Castle Gardens	8·44	254	,,	Balbriggan, Ardgillan	3·52	154
Forf.	Kettins School	6·61	279	*Me'th*	Beauparc, St. Cloud	3·31	...
,,	Dundee, E. Necropolis	4·43	227	,,	Kells, Headfort	4·66	148
,,	Pearsie House	6·73	...	*W.M*	Moate, Coolatore	3·84	...
,,	Montrose, Sunnyside	4·32	217	,,	Mullingar, Belvedere	4·98	155
Aber.	Braemar, Bank	6·63	208	*Long*	Castle Forbes Gdns.	6·00	180
,,	Logie Coldstone Sch.	3·73	169	*Gal.*	Ballynahinch Castle	10·47	169
,,	Aberdeen, King's Coll.	3·80	174	,,	Galway, Grammar Sch.	5·71	...
,,	Fyvie Castle	3·02	...	*Mayo*	Mallaranny	12·67	...
Mor.	Gordon Castle	2·96	147	,,	Westport House	7·60	163
,,	Grantown-on-Spey	3·71	153	,,	Delphi Lodge	15·98	...
Na.	Nairn, Delnies	3.43	172	*Sligo*	Markree Obsy.	7·48	190
Inv.	Ben Alder Lodge	11·35	...	*Cav'n*	Belturbet, Cloverhill	4·94	165
,,	Kingussie, The Birches	7·31	...	*Ferm*	Enniskillen, Portora	7·35	...
,,	Loch Quoich, Loan	24·00	...	*Arm.*	Armagh Obsy.	4·84	192
,,	Glenquoich	21·11	154	*Down*	Fofanny Reservoir	12·93	...
,,	Inverness, Culduthel R.	5·21	...	,,	Seaforde	6·37	202
,,	Arisaig, Faire-na-Squir	8·78	...	,,	Donaghadee, C. Stn.	5·47	215
,,	Fort William	16·75	174	,,	Banbridge, Milltown	3·77	168
,,	Skye, Dunvegan	12·06	...	*Antr.*	Belfast, Cavehill Rd.	7·07	...
R&C	Alness, Ardross Cas.	6·71	177	,,	Glenarm Castle	8·66	...
,,	Ullapool	8·81	...	,,	Ballymena, Harryville	7·41	200
,,	Torridon, Bendamph	17·55	187	*Lon.*	Londonderry, Creggan	7·72	214
,,	Achnashellach	13·94	...	*Tyr.*	Donaghmore	7·51	...
,,	Stornoway	...	...	,,	Omagh, Edenfel	7·66	216
Suth.	Lairg	6·98	...	*Don.*	Malin Head	7·36	282
,,	Tongue	7·61	193	,,	Dunfanaghy	8·64	213
,,	Melvich	5·03	152	,,	Killybegs, Rockmount	13·12	234

Climatological Table for the British Empire, August, 1927

STATIONS	PRESSURE Mean of Day M.S.L.	PRESSURE Diff. from Normal	TEMPERATURE Absolute Max.	TEMPERATURE Absolute Min.	TEMPERATURE Mean Values Max.	TEMPERATURE Mean Values Min.	TEMPERATURE Mean Values ½ max. and min.	TEMPERATURE Mean Values Diff. from Normal	TEMPERATURE Mean Wet Bulb	Relative Humidity	Mean Cloud Am'nt	PRECIPITATION Am'nt	PRECIPITATION Diff. from Normal	PRECIPITATION Days	BRIGHT SUNSHINE Hours per day	BRIGHT SUNSHINE Percentage of possible
	mb.	mb.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	%	0—10	in.	in.			
London, Kew Obsy.	1012·1	− 3·2	76	47	68·7	55·2	61·9	+ 0·3	56·5	89	6·9	4·07	+ 1·83	17	5·6	38
Gibraltar	1015·9	− 0·8	94	63	83·6	68·7	76·1	+ 0·1	66·3	78	4·2	0·07	− 0·06	1	...	...
Malta	1015·2	− 0·1	98	68	85·6	74·8	80·2	+ 1·1	73·9	79	1·6	0·00	− 0·14	0	12·1	90
St. Helena	1016·4	+ 2·8	66	52	60·6	54·2	57·4	− 0·5	55·2	91	3·5	3·04	− 0·68	21	...	...
Sierra Leone	1013·6	+ 0·9	87	69	82·5	71·8	77·1	− 0·8	74·2	85	8·5	22·02	−14·55	24	...	...
Lagos, Nigeria	1013·0	− 0·6	82	71	80·2	73·5	76·9	− 0·8	73·2	83	3·1	0·25	− 2·55	5	...	...
Kaduna, Nigeria	1015·8	+ 2·0	86	...	81·1	...	...	...	70·6	89	...	12·83	+ 3·15	28	...	...
Zomba, Nyasaland	1017·4	+ 0·6	83	44	75·8	50·6	63·2	− 1·7	...	75	2·5	0·04	− 0·33	2	...	...
Salisbury, Rhodesia	1016·3	− 1·0	84	38	73·5	46·5	60·0	− 0·2	51·9	53	1·5	0·04	− 0·04	1	9·6	83
Cape Town	1019·6	− 0·6	87	41	66·0	49·0	57·5	+ 1·9	51·0	88	5·0	5·08	+ 1·69	9	...	...
Johannesburg	1021·6	− 0·1	70	27	63·4	41·2	52·3	− 2·0	41·8	46	1·4	0·07	− 0·44	1	9·5	86
Mauritius	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bloemfontein	...	...	73	25	64·0	37·2	50·6	− 1·6	40·6	67	3·1	0·72	+ 0·25	2	...	...
Calcutta, Alipore Obsy.	1001·1	+ 0·1	93	77	88·8	79·0	83·9	+ 0·9	79·5	89	8·2	7·02	− 5·67	15*	...	...
Bombay	1005·7	− 0·2	85	76	84·0	77·2	80·6	− 0·1	76·1	86	8·3	6·74	− 7·71	25*	...	...
Madras	1005·8	+ 0·3	100	74	95·4	78·9	87·1	+ 1·2	76·2	71	7·2	3·71	− 0·93	8*	...	...
Colombo, Ceylon	1009·9	+ 0·2	89	73	86·9	77·2	82·1	+ 1·0	77·8	76	7·5	0·52	− 2·61	9	7·2	58
Hongkong	1003·5	− 1·6	93	74	87·5	78·0	82·7	+ 0·6	79·4	86	7·5	20·91	+ 6·86	19	6·8	53
Sandakan	...	...	91	73	89·2	75·2	82·2	+ 0·4	76·8	85	...	8·07	+ 0·01	13	...	...
Sydney	1015·8	− 2·4	78	39	65·3	45·6	55·5	+ 0·5	47·5	59	1·3	0·30	− 2·71	5	8·6	79
Melbourne	1014·9	− 3·2	70	37	57·8	44·0	50·9	− 0·2	46·2	73	7·0	1·93	+ 0·12	21	4·4	41
Adelaide	1016·9	− 2·4	74	40	61·6	46·4	54·0	0·0	48·7	71	6·0	3·79	+ 1·28	20	5·3	49
Perth, W. Australia	1017·1	− 1·7	70	38	63·8	49·6	56·7	+ 0·8	52·8	75	6·7	6·49	+ 0·87	24	5·5	50
Coolgardie	1017·4	− 1·9	77	36	64·8	43·2	54·0	+ 0·4	48·2	62	3·9	0·49	− 0·53	7	...	...
Brisbane	1017·8	− 1·4	81	40	72·9	46·2	59·5	− 0·9	50·9	56	1·5	0·27	− 1·86	1	9·7	87
Hobart, Tasmania	1008·5	− 5·1	66	34	54·3	41·2	47·7	− 0·3	42·7	69	6·0	1·19	− 0·65	22	5·1	49
Wellington, N.Z.	1008·4	− 6·7	63	31	54·0	42·6	48·3	− 0·3	46·5	81	7·3	7·38	+ 2·89	23	4·1	39
Suva, Fiji	1013·3	− 1·0	88	66	80·3	71·1	75·7	+ 2·0	71·9	85	7·7	9·14	+ 0·90	23	4·1	36
Apia, Samoa	1012·5	+ 0·3	86	71	85·0	75·2	80·1	+ 2·3	76·4	77	4·8	1·36	− 1·79	16	8·4	72
Kingston, Jamaica	1013·3	− 0·2	93	70	89·7	73·2	81·5	0·0	72·1	84	3·4	2·83	− 0·72	6	9·2	72
Grenada, W.I.	1008·8	− 3·8	92	71	87·7	75·9	81·8	+ 2·3	77·0	75	3·4	3·46	− 6·12	18	...	...
Toronto	1015·9	+ 0·5	85	48	74·7	55·0	64·9	− 1·7	57·4	73	3·6	1·47	− 1·30	4	7·2	51
Winnipeg	1016·1	+ 2·2	88	36	74·7	51·9	63·3	+ 0·3	53·5	85	4·3	2·85	+ 0·41	9	7·8	54
St. John, N.B.	1014·9	− 0·5	76	47	67·1	53·5	60·3	− 0·3	57·3	85	6·4	8·96	+ 5·10	12	...	...
Victoria, B.C.	1015·9	− 1·3	85	49	67·8	52·5	60·1	0·0	55·9	75	3·8	0·48	− 0·17	5	9·9	69

*For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

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Toronto	1015·9	+ 0·5	85	48	74·7	55·0	64·9	− 1·7	57·4	73	3·6	1·47	− 1·30	4	7·2	51
Winnipeg	1016·1	+ 2·2	88	36	74·7	51·9	63·3	+ 0·3	53·5	85	4·3	2·85	+ 0·41	9	7·8	54
St. John, N.B.	1014·9	− 0·5	76	47	67·1	53·5	60·3	− 0·3	57·3	85	6·4	8·96	+ 5·10	12	...	...
Victoria, B.C.	1015·9	− 1·3	85	49	67·8	52·5	60·1	0·0	55·9	75	3·8	0·48	− 0·17	5	9·9	69

*For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

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28